Argonne NATIONAL LABORATORY

Underlying event studies using calorimeter clusters

status report

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May 27, 2010

ATLAS SM Meeting

U.S. DEPARTMENT OF ENERGY

Introduction

- **Thanks to all people participating in this analysis.**
- **Many elements have been taken from the tracking UE studies + calorimeter-performace studies**
- **https://twiki.cern.ch/twiki/bin/view/AtlasProtected/TopoClustersUE**

TopoClustersUE

- Studies of particle flow using calorimeter clusters in pp collisions at 900 GeV and 7 TeV with the ATLAS detector at the LHC
  - People
  - Paper outline
  - Introduction
  - Supporting material
    - Notes
    - Talks
    - Histograms and figures
  - Proposed final plots
  - Analysis Code
    - Topocluster energy scale

Studies of particle flow using calorimeter clusters in pp collisions at 900 GeV and 7 TeV with the ATLAS detector at the LHC

People

C. Bertella , A. Buckley, S. Chekanov , P. Giovaninni , N. Kanaya ,D. Kar, A. Moraes, S. Menke , J. Nielsen, G.A. Hare, J. Proudfoot , C. Roda , P.Starovoitov, I. Vivarelli , R. Yoshida , J. Zhang

Contains drafts, talks, paper outline, CONF draft

Introduction

- https://twiki.cern.ch/twiki/bin/view/AtlasProtected/TopoClustersUE

ATL-COM-PHYS-2010-210

ATLAS NOTE

May 14, 2010

Underlying event particle flow based on calorimeter clusters in pp collisions at 900 GeV with the ATLAS detector at the LHC

C. Bertella[a], S. Chekanov[b], P. Giovaninni[c], N. Kanaya[d], S. Menke[c], J. Proud
P. Starovoitov[e], I. Vivarelli[f], R. Yoshida[b], J. Zhang[b]

ATL-COM-PHYS-2010-293

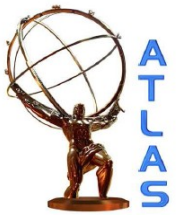
Draft version 1.0

ATLAS NOTE

May 14, 2010

Underlying event particle flow based on calorimeter clusters in pp collisions at 7 TeV with the ATLAS detector at the LHC

C. Bertella[a], S. Chekanov[b], P. Giovaninni[c], N. Kanaya[d], S. Menke[c], J. Proudfoot[b], C. Roda[a], P. Starovoitov[e], I. Vivarelli[f], R. Yoshida[b], J. Zhang[b]



Draft version 1.0

ATLAS NOTE

May 14, 2010

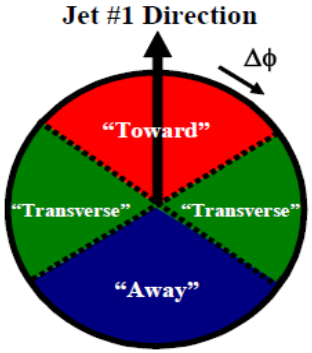
CONF note draft:

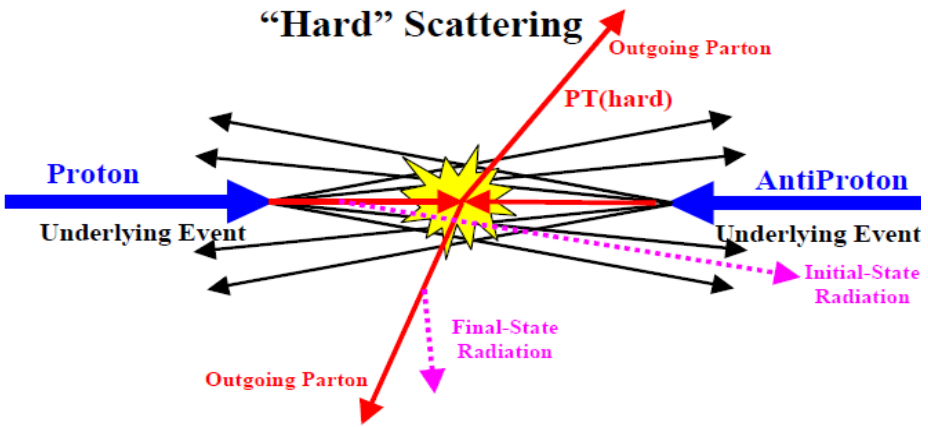
Studies of particle flow using calorimeter clusters in pp collisions at 900 GeV and 7 TeV with the ATLAS detector at the LHC

C. Bertella[a], A. Buckley[b], S. Chekanov[c], P. Giovaninni[d], G.A. Hare[e], N. Kanaya[f], D. Kar[d], S. Menke[g], J. Nielsen[e], J. Proudfoot[c], C. Roda[a], P. Starovoitov[g], I. Vivarelli[h], R. Yoshida[c], S. Wahrmund[d], J. Zhang[c]

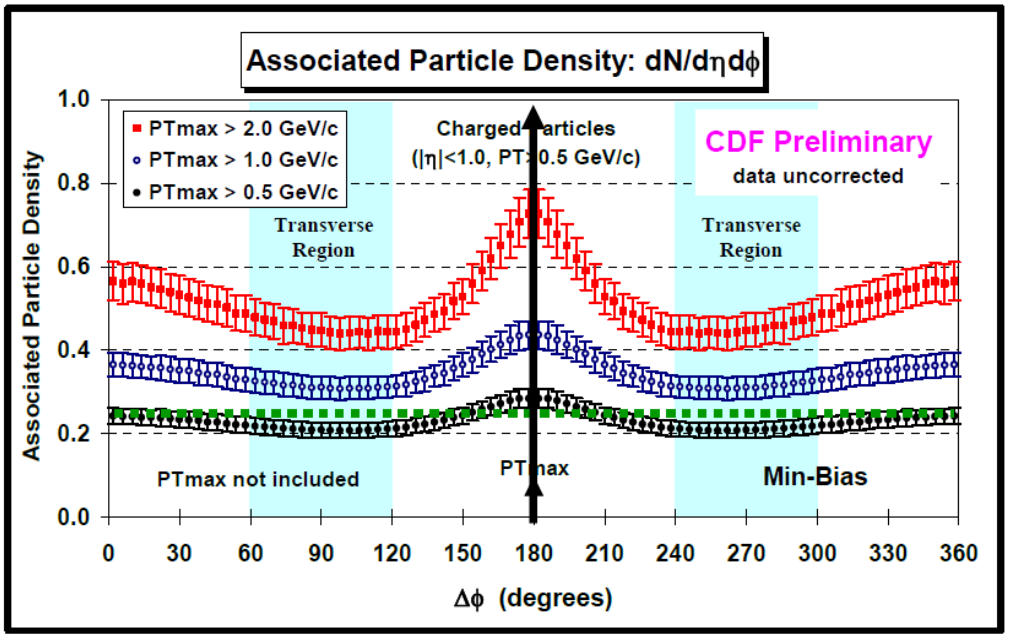
Introduction to UE studies

R.Field,
Acta Phys. Pol. B
36, No. 2 (2005) 167





A typical example of the UE studies

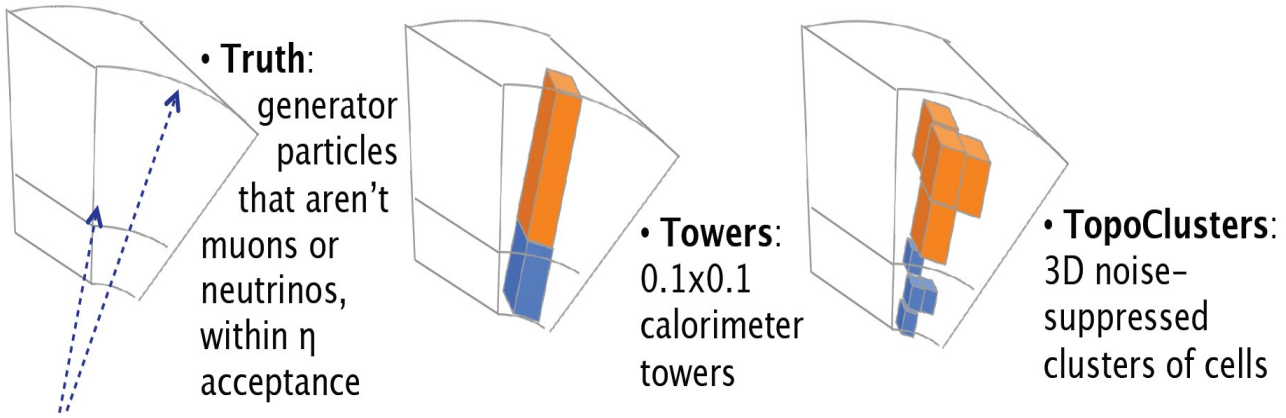


The "underlying event" consists of
- hard initial & final-state radiation
- beam-beam remnants
- possible multiple parton interactions

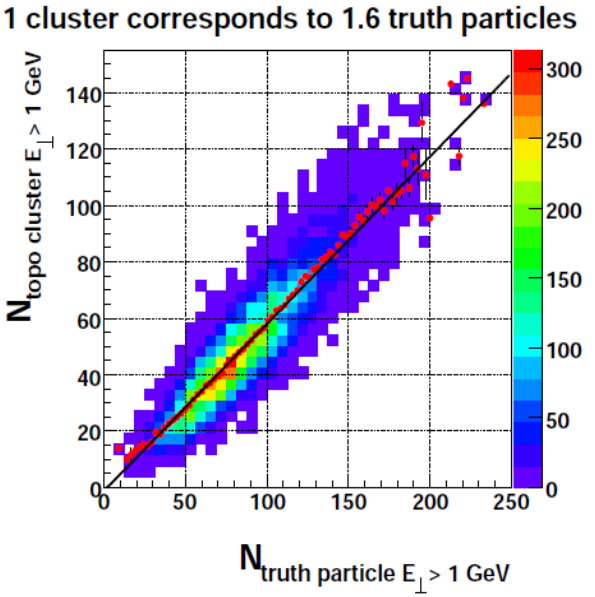
- **ATLAS UE studies based on tracks:**
  - ATL-COM-PHYS-2010-164
  - ATL-COM-PHYS-2010-165
  - ATL-COM-PHYS-2010-175
  - ATL-COM-PHYS-2010-237
  - ATL-COM-PHYS-2010-238 - **CONF note**

UE studies using topoclusters

- **Use calorimeter measurements taking advantage a fine calorimeter granularity**
  - **Systematically completely independent of tracking**
    - Do we see the same discrepancies with MC as for the tracking analysis?
  - **Look at a complete final state (charged & neutral particles).**
    - + additional 40% of final state not seen by the tracking analysis
  - **More relevant for future jet-based studies**
    - Where the UE is the main issue for precision measurements
- **Topoclusters are the natural choice for such measurements:**
  - provide efficient noise and pile-up suppression
  - correspond to individual hadrons



(From a P.Loch's talk)



(S.Menke talk, 2008)

Event & Topocluster selection: 900 GeV

- Good runs: 141565, 141707,141746,141748,141811,142166,142191,142193,142195,142383
- Monte Carlo sample: ATLAS-GEO-08-00-02 (r1051)
- L1_MBTS_1 trigger. Good primary vertex

TopoClusters:

- Topoclusters after local hadronic calibration (EM-scale as systematics checks)
- Concentrate on the central region |eta|<2.5 (easy cross check with tracks)
- pT>500 MeV and above (as for the tracking analysis)

Event & Topocluster selection: 7 TeV

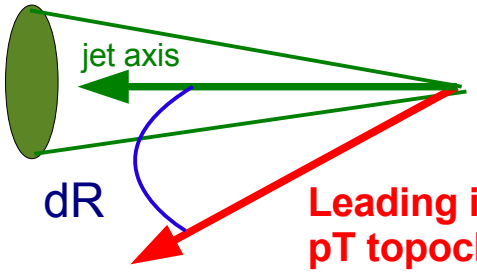
- Good run & lumi blocks for 152166- 152844. Lumi ~ 238 μb^{-1}
- Same event cuts as for 900 GeV + pile-up removal
- Same cuts on topoclusters

QCD predictions

PYTHIA MC09	- pT ordered shower, tuned to pp(bar) data.	- **Main MC for unfolding**
PYTHIA Perujia0	- tuned using only MinBias data from pp(bar)	- (used for systematics studies)
PYTHIA DW	- virtuality-ordered parton shower + max ISR	- (only for truth comparison)
PHOJET	- better description of hard diffraction	- (used for systematics studies)

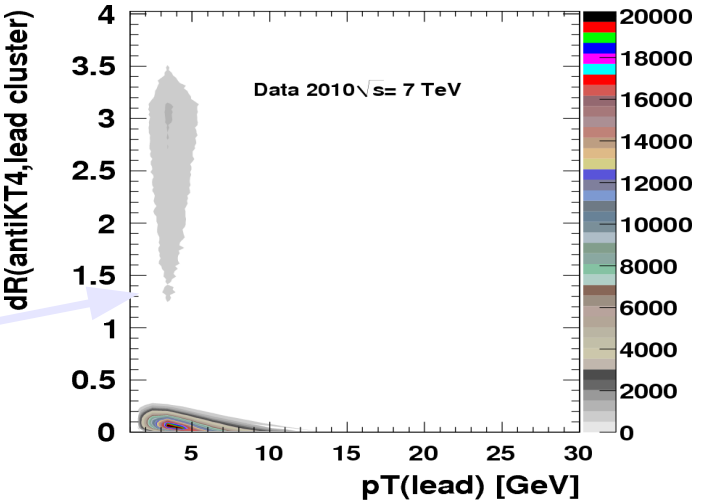
Topocluster properties for the UE studies

- **Good match between the jet axis and a leading topocluster**



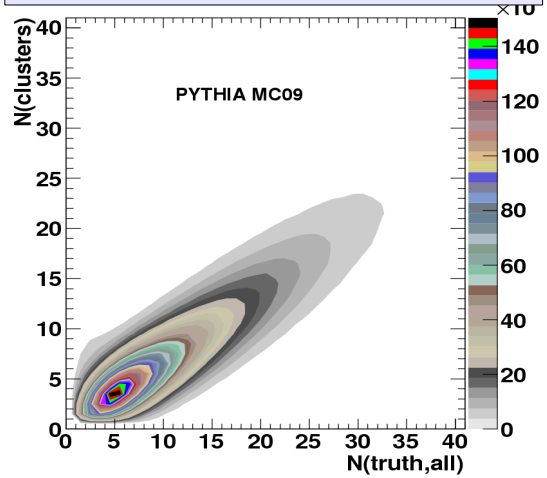
dR – a distance (in η and φ) between a leading topocluster and anti-KT jet

38.4% (data)
39.3% (MC09)

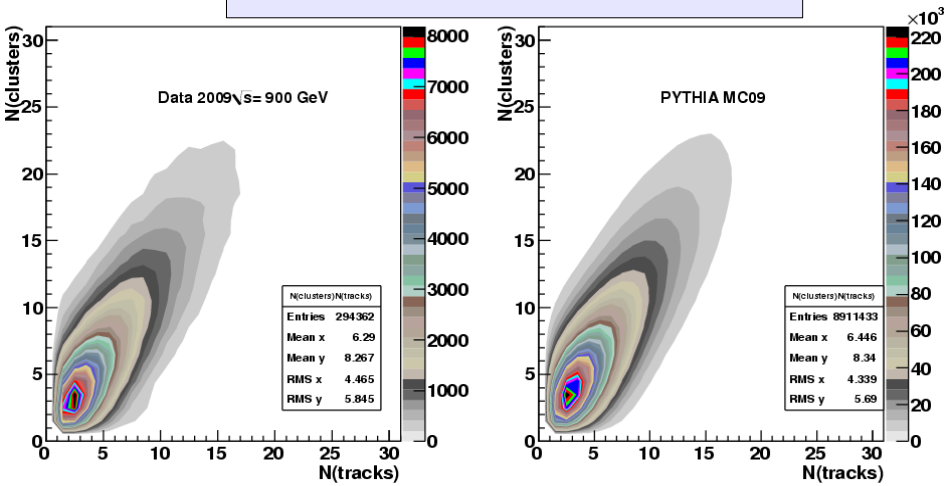


- **Good association with the number of truth hadrons & reasonable description by MC**

Clusters vs truth particles



Clusters vs Tracks



See profile plots, comparisons in slices etc. in **ATL-COM-PHYS-2010-210**

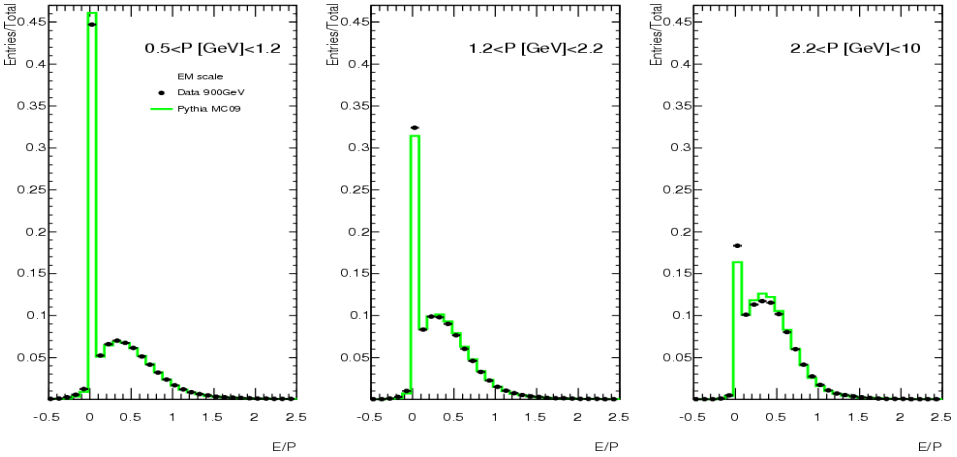
- **Good position measurements. Agreement with MC**
  - **See April's workshop on jet reconstruction (J.Proudfoot etc..)**

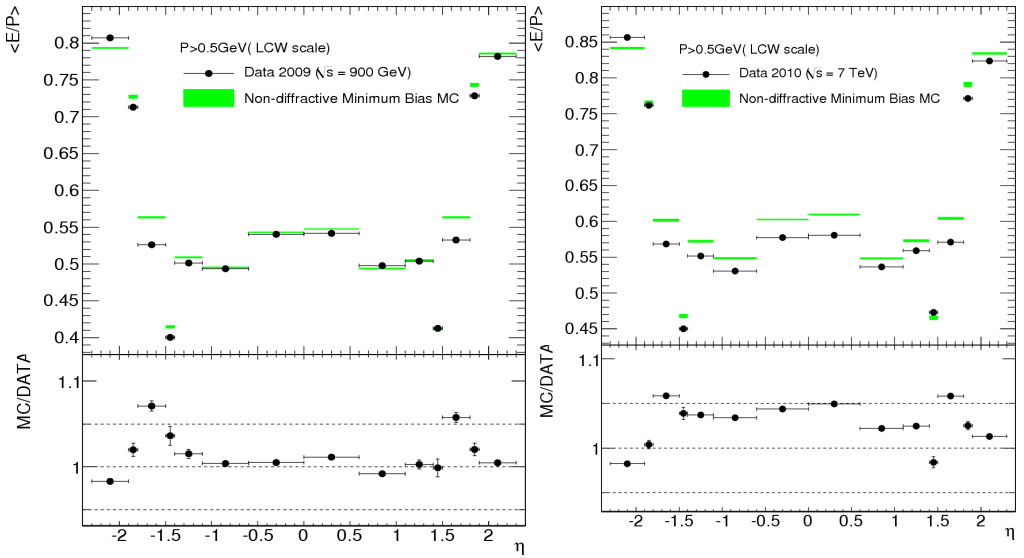
Energy-scale measurements

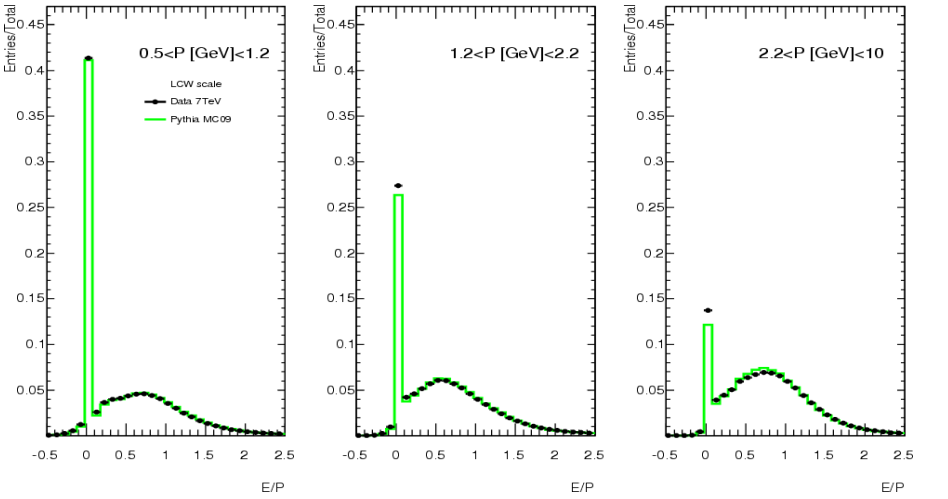
http://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=paper&confId=87760

From P.Starovoitov

- Compare <E/p> for data and MC
- Many studies by several groups
- Agreement within 3% in most regions, and ~10% in the transition region
- Use data/MC ratios in a grid in η-P for systematics studies (not what shown here!)





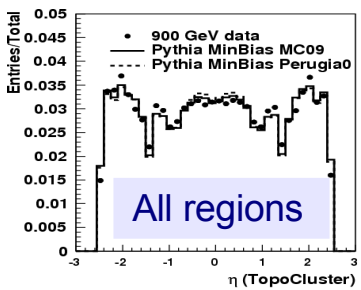


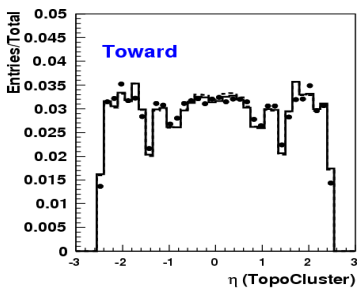
For hadronic TopoClusters, data and MC agree for calibrated and uncalibrated clusters within ~4%

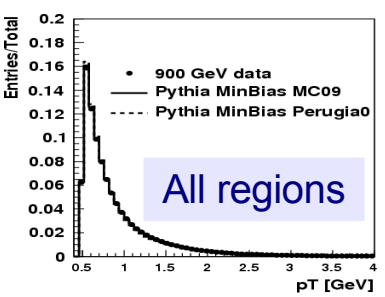
- For trackless clusters, see J.Zhang's talk :

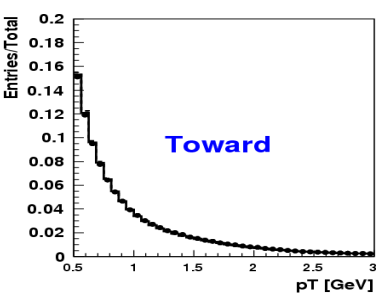
http://indico.cern.ch/getFile.py/accesscontribId=49&sessionId=6&resId=0&materialId=slides&confId=88935

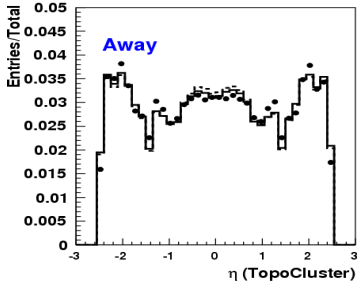
TopoCluster properties at 900 and 7 TeV GeV

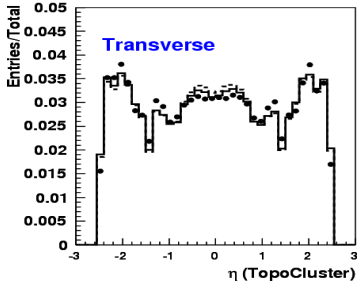


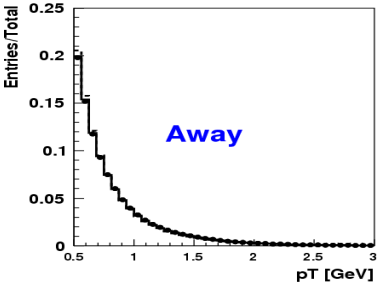


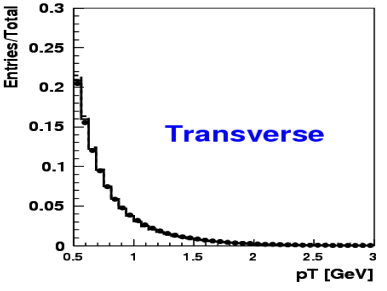




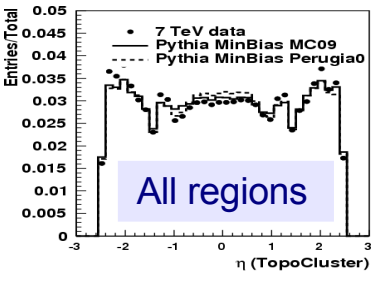


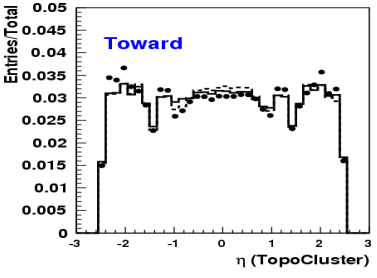


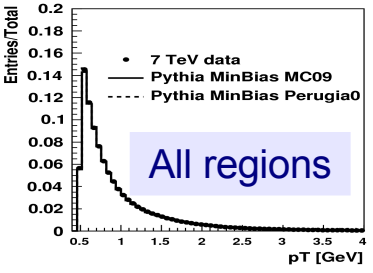


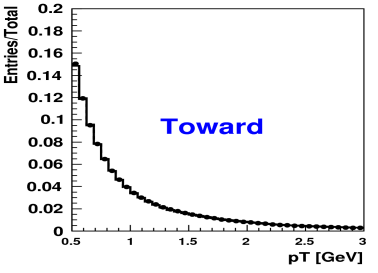


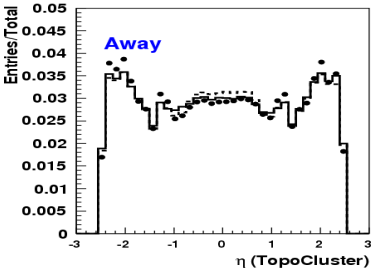
900 GeV

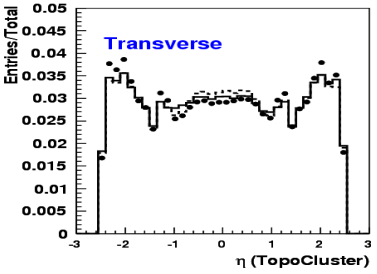


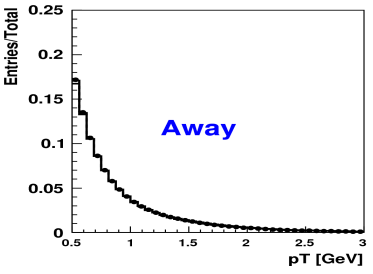


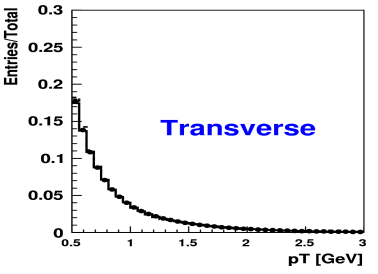










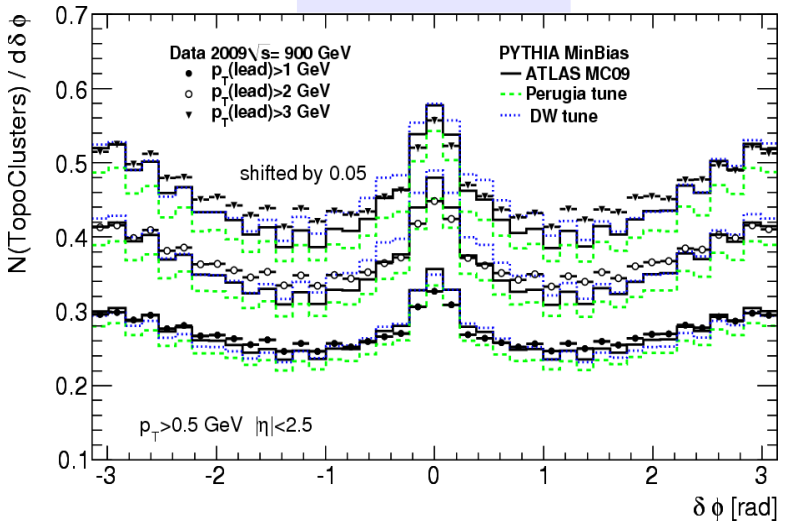


7 TeV

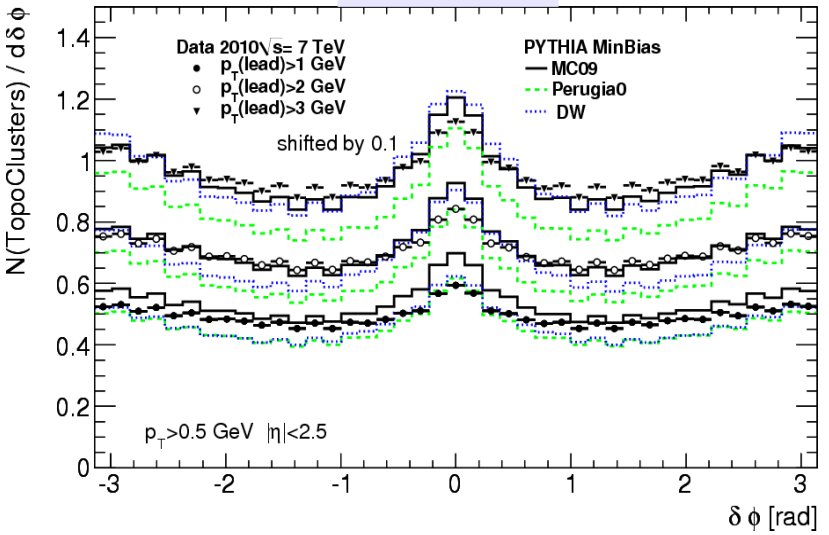
- **Reasonable agreement with MC09 & Perugia0 tunes**

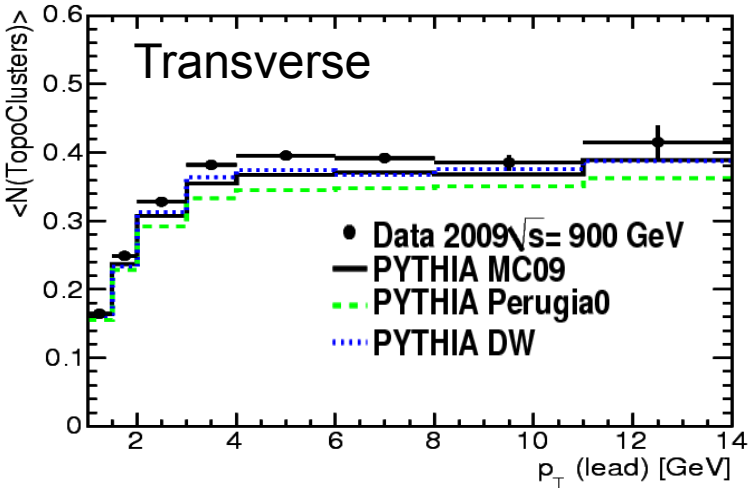
Detector-level distributions

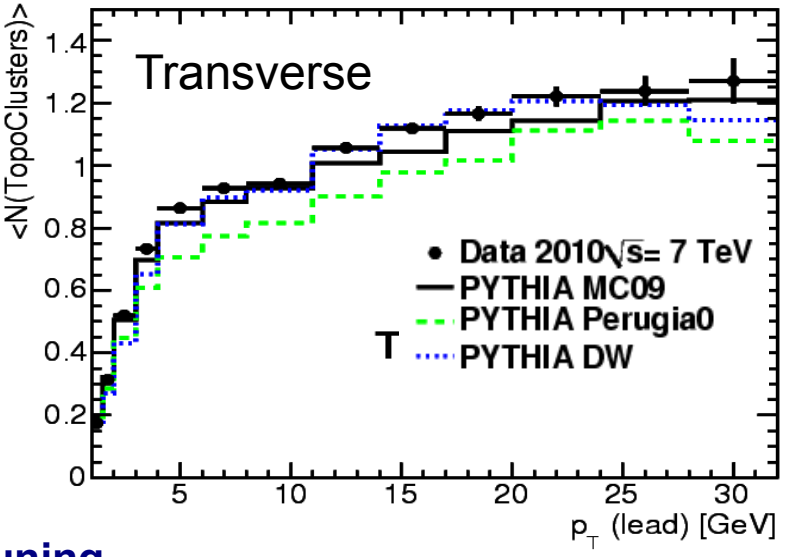
900 GeV



7 TeV







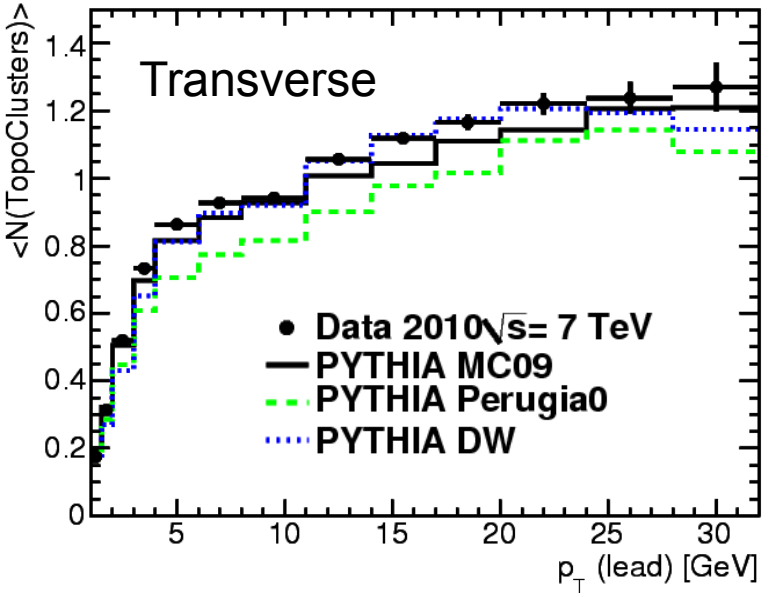
Sensitivity to MC tunes. Can be used for MC tuning

- unfold the distributions to the truth level to simplify the task

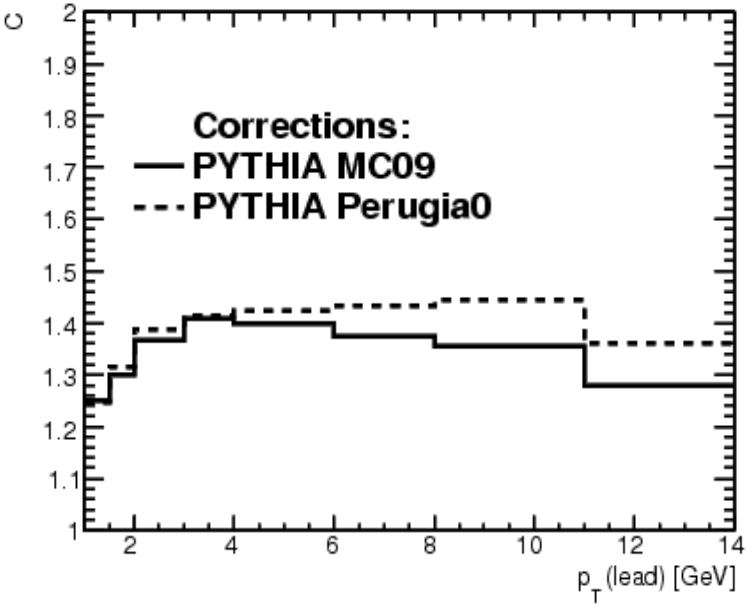
No single MC tune with a good description of all distributions.

Example of the correction procedure

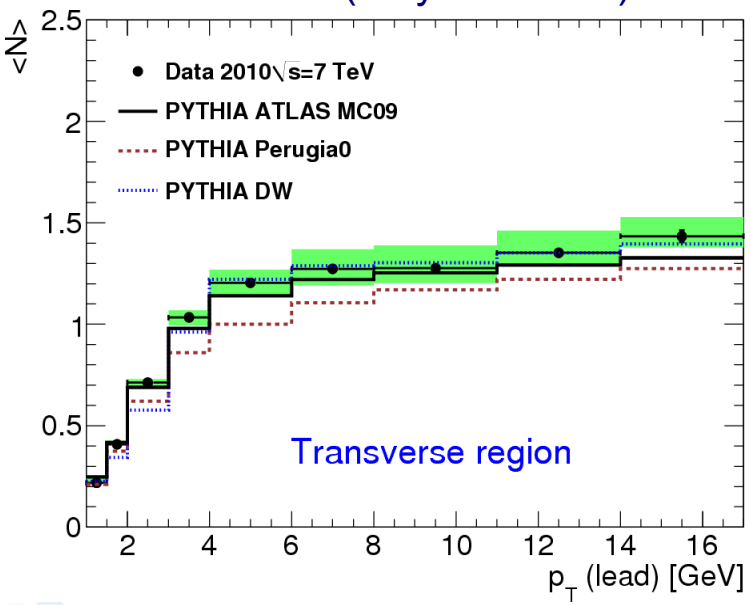
detector-level



Bin-by-bin correction



Corrected (+ systematics)



Bin-by-bin correction

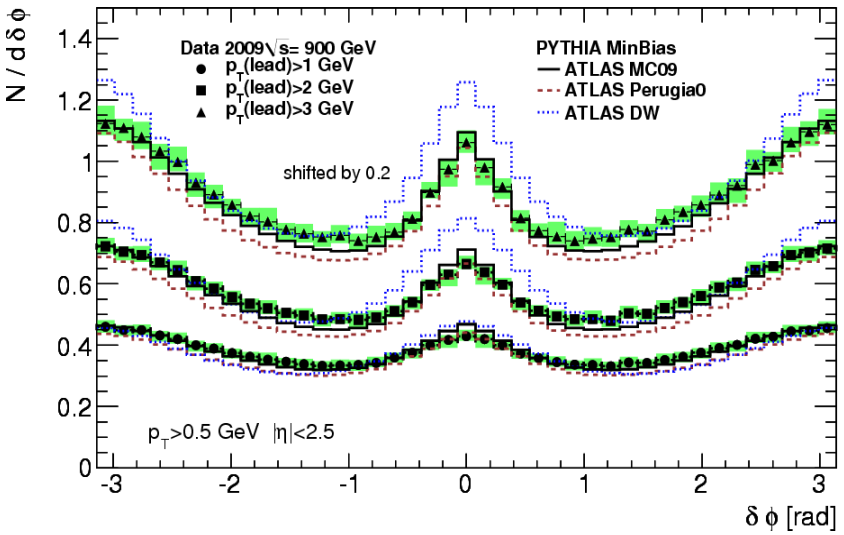
C= N(gen)/N(reco) = purity / efficiency

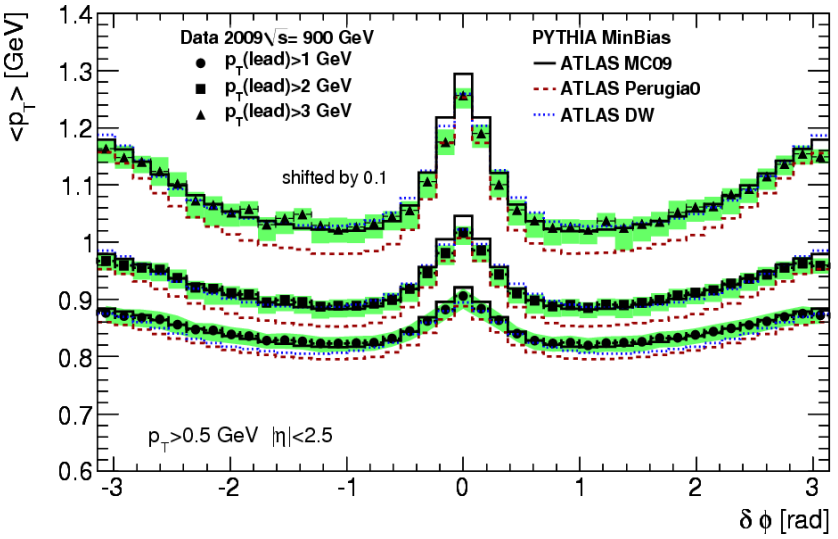
- **Validated using our track-based UE/MinBias studies**
  - ATL-COM-PHYS-2010-165 and ATL-COM-PHYS-2010-237

- **Example of worst-case correction (50%)**
- **Other distributions have smaller corrections**

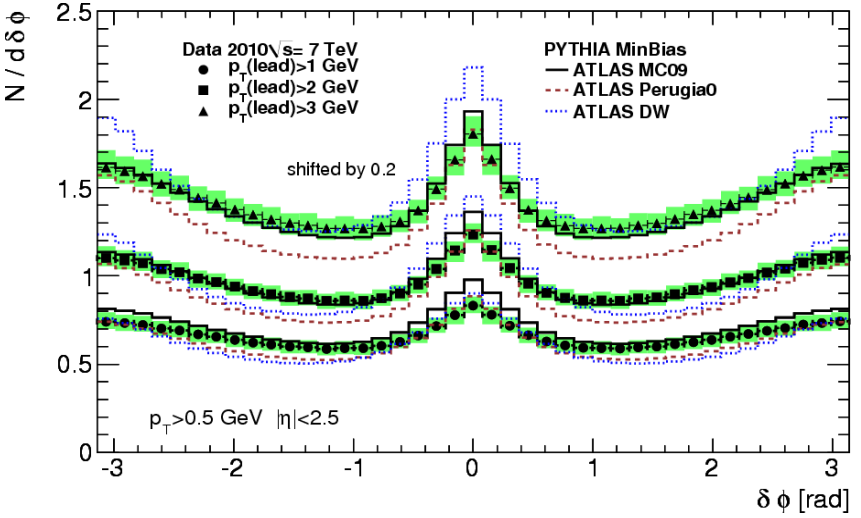
Final results

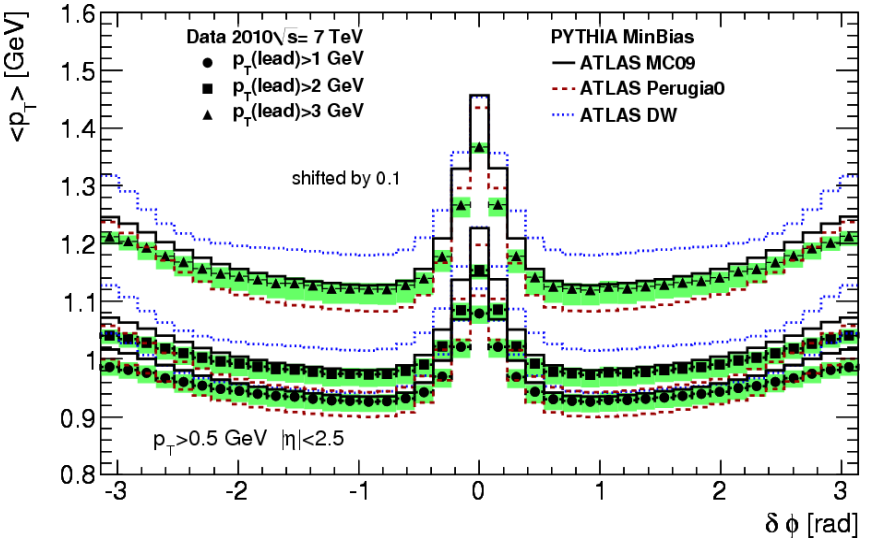
900 GeV





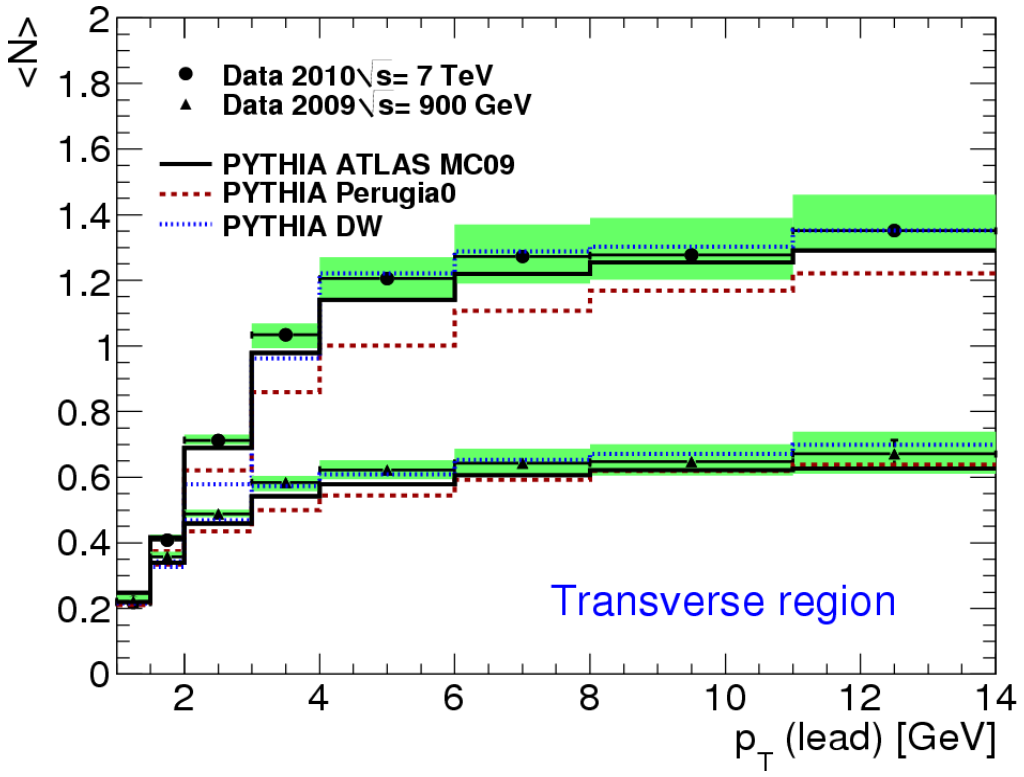
7 TeV

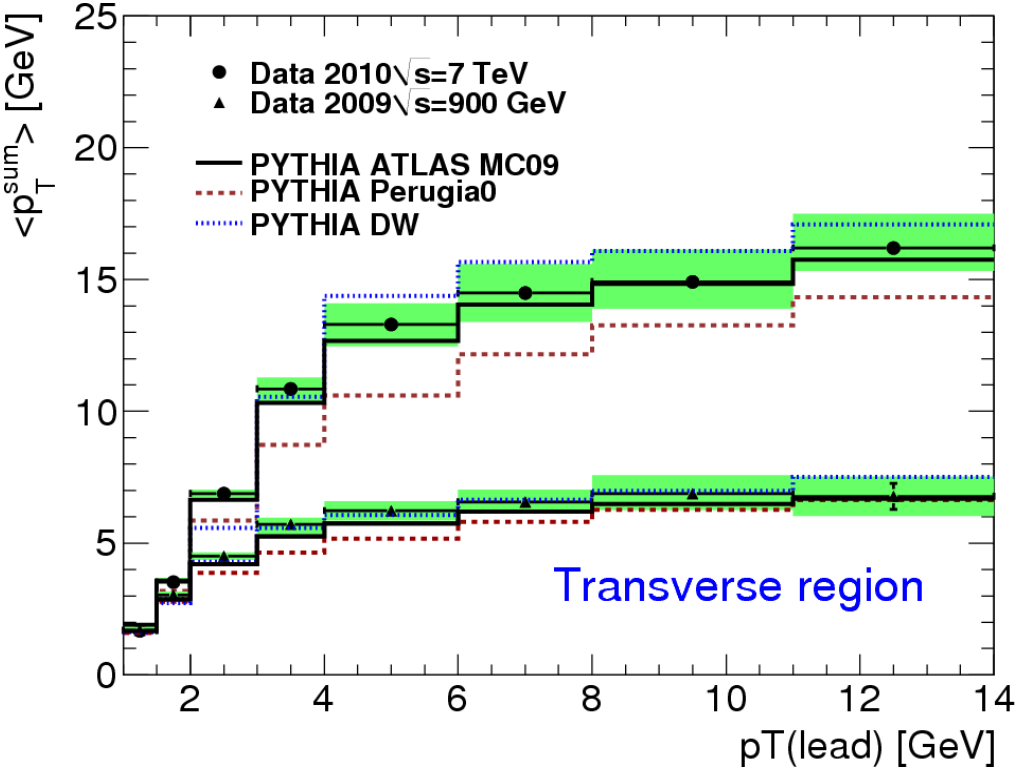




Perugia0 and DW are disfavored. Some (smaller) problems with MC09

Final results

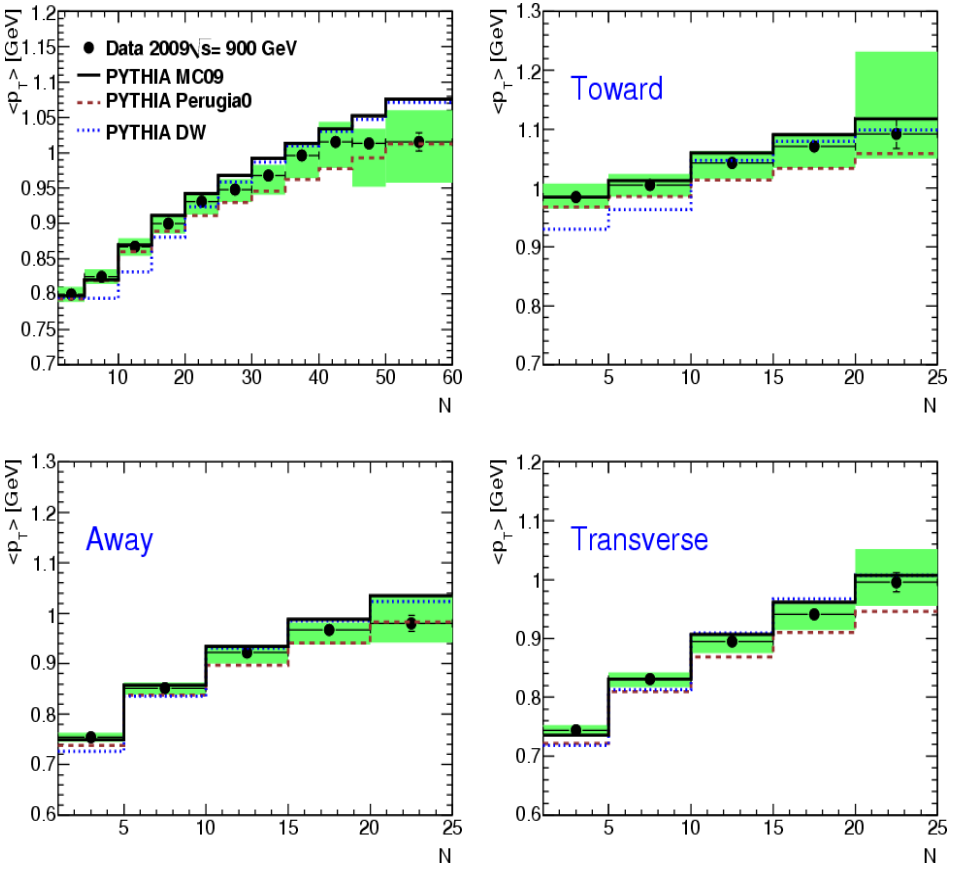




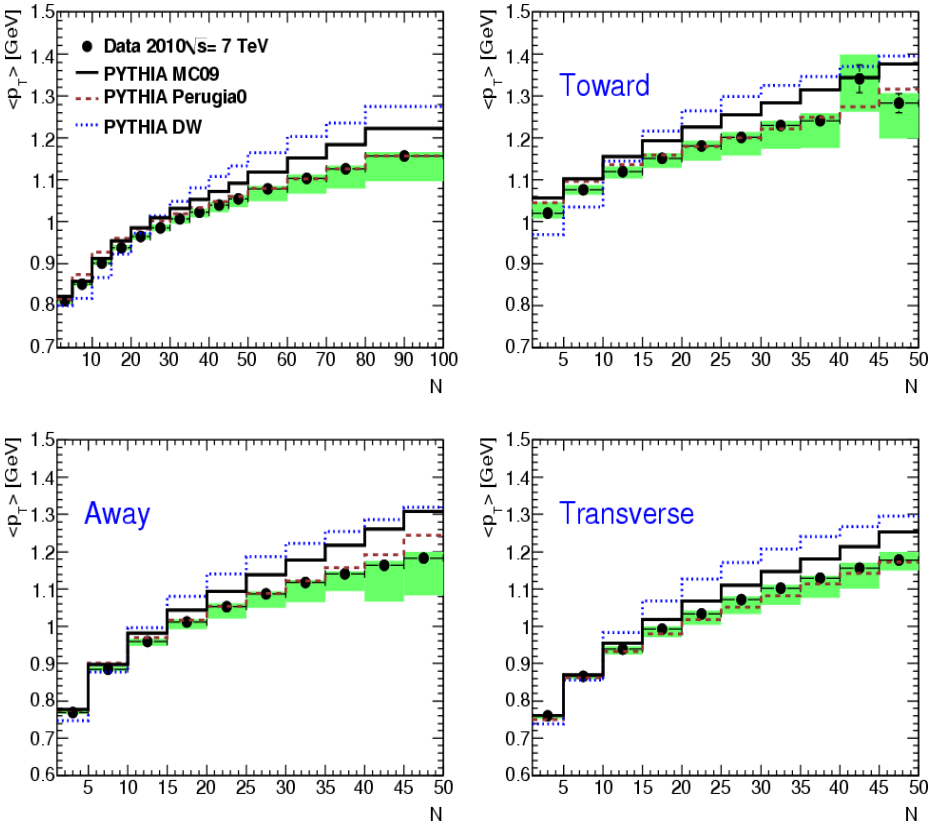
DW and MC09 are closest to data, but within the systematic-uncertanty band
Perugia0 underestimates the data

Final results

900 TeV



7 TeV



Perugia0 describes the data well

Summary

- **First UE measurements using calorimeter objects**
  - Directly relevant for future calorimeter-based measurements
  - Studies are sensitive to the entire hadronic final state (+40% compare to the tracking analysis)
- **Provide systematically independent check of our track-based measurements**
  - Additional constraint on the UE understanding & model tunings
- **TopoClusters measurements confirm the conclusions for charged-particle UE studies.**
  - No MC tunes with good description of all observables
  - MC tunes have smaller particle activity in the transverse regions
    - systematically below the data in the transverse region
    - but the discrepancies are not too strong given the large systematic uncertainties

Two technical notes are ready, CONF note is available

Backup slides

Correction procedure

- **All distributions are measured with respect to "reference" particles**
- **Mismeasured particle introduces smearing (lower purity in bins)**
- **Can be taken into account using a bin-by-bin correction:**

C= N(gen)/N(reco) = purity / efficiency

Corrects for:

- event selection
- clusters selection (inefficiencies due to threshold cut effect, losses, merging/splitting etc.)
- resolution smearing (leading cluster is lost), other impurity effects
- decays of long-lived resonances (truth level is defined by $\tau < 3\ 10^{-10}$ sec)

- **Resolution smearing is minimized choosing bin sizes larger than resolutions in each bin**
- **Model dependence is controlled using alternative MCs**
- **Tested using track-based MinBias studies (fully agrees with the track-weighting approach)**
  - ATL-COM-PHYS-2010-165 and ATL-COM-PHYS-2010-237
- **No correction for diffraction was applied:**
  - Single and Double diffraction is expected at the level of:
    - <1% for PYTHIA (SD/DD) when pT>1 GeV
    - ~1% for PHOJET (SD/DD) – more diffractive events at pT>1 GeV (hard diffraction), but SD/DD are similar in shape and show a small contribution to the final densities
- **Only measurements are presented where the correction factor are understood and <50%**

Systematic uncertainties

- Reject events with N(clusters)<3 (diffraction)
- Energy scale using the grid in η-P (to take into account 10% uncertainty in the transition region)
  - Includes +3 MeV shift to account for the difference between data and MC for pi0 peak
- ± 0.025 rad for cluster centers φ and η (shift by 1 Ecell)
- (a) PYTHIA with 10% extra material; (b) with improved PP0 geometry
  - http://cdsweb.cern.ch/record/1243587
- Using Peruji0 for unfolding (model dependence)
  - A typical difference between bin-by-bin corrections ~1.5%
- Entire analysis repeated using EM-scale clusters

Check	$N/d\delta\phi$	$< p_T >$ vs N	$< N >$ vs $p_T(lead)$
Event selection	$\pm 0.5\%$	$\pm 0.5\%$	1.5%
Energy scale	$\pm 4.7\%$	$\pm 1.2\%$	$\pm 5\%$
ϕ positions	$\pm 1.3\%$	$\pm 0.2\%$	$\pm 0.2\%$
η positions	$\pm 0.2\%$	$\pm 0.2\%$	$\pm 0.2\%$
Additional material	$\pm 0.5\%$	$\pm 0.8\%$	$\pm 1.8\%$
Model dependence	$\pm 1.5\%$	$\pm 1.0\%$	$\pm 1.5\%$